PTX 1065

SUTTIE E-3

TURBOMECA

Sundstrand Power Systems / TURBOMECA
APS 3000 APU
COORDINATION MEMO

MEMO n° TS 332-0534
DATE : October 25, 1991
REPLY BY :

☐ REQUEST
☐ INFORMATION
☒ REPLY TO : ST 0539

REMAND
PTX 1065

TO : R.A. WHITE/T. VEALE FROM : G. HARDY
A. DUCROCQ
SUBJECT : LOAD COMPRESSOR FLOW MEASUREMENTS

REFERENCE : TS 332-0428

The following referenced information is [X] (or is not [ ]) considered "PROPRIETARY" by the originator

1. In what part of Airbus specifications does appear the requirement of load compressor corrected flow transmission to the onboard computer ?

   If necessary, what corrected flow is to be transmitted :

   W'o (plenum inlet) or W'7 (scroll outlet) ?

2. For surge control, the effective minimum value $\Delta P/P$ has to be assessed in complet aboard engine configuration (actual onboard pressure losses, bleed valve, ...). Furthermore, it can be seen that high values of W'7 correspond to very low pressure ratios and hard choke conditions which are not included in the Duty Cycle (limit values are about 0.60 for W'7 and 0.40 for $\Delta P/P$).

3. Airflow sensor characteristics (compressor rig test with plenum and for various IGV angles (- 15° to + 82°) are given p. 3/4 [$\Delta P/P = (Pst7 - Pst)/Pst7$ vs . W7] and page 4/4 [$\Delta P/P = (Pt7 - Ps)/Pt7$ vs. W'7] for the averaged static pressure (measured with 3 pressure taps located as on the engine. At $\Delta P/P \sim 0.20$, the scattering $\delta W'7$ is about 6.9 % and at $\Delta P/P = 0.25$ $\delta W'7 = 4.7$ %. This scattering should be lower with a 19 taps averaged static pressure, as planned on engine. All the measurements taken into account were done with a constant axial running clearance because axial clearance seems to have an effect on the relation $\Delta P/P = f(W'7)$.

   Preliminary averaged curves defined in memo TS 332-0428 were slightly different (same slope but higher W'7) because they were taking into account less points (only 0° and + 10° IGV setting) with various axial clearances. The future engine conditions being different from rig test conditions (axial clearance, 19 taps averaged static pressure), the present curves must be considered as preliminary ones by are probably closed of final curves.

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APPROVED BY: G. HARDY DATE: Oct/25/91

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APS 3000 APU

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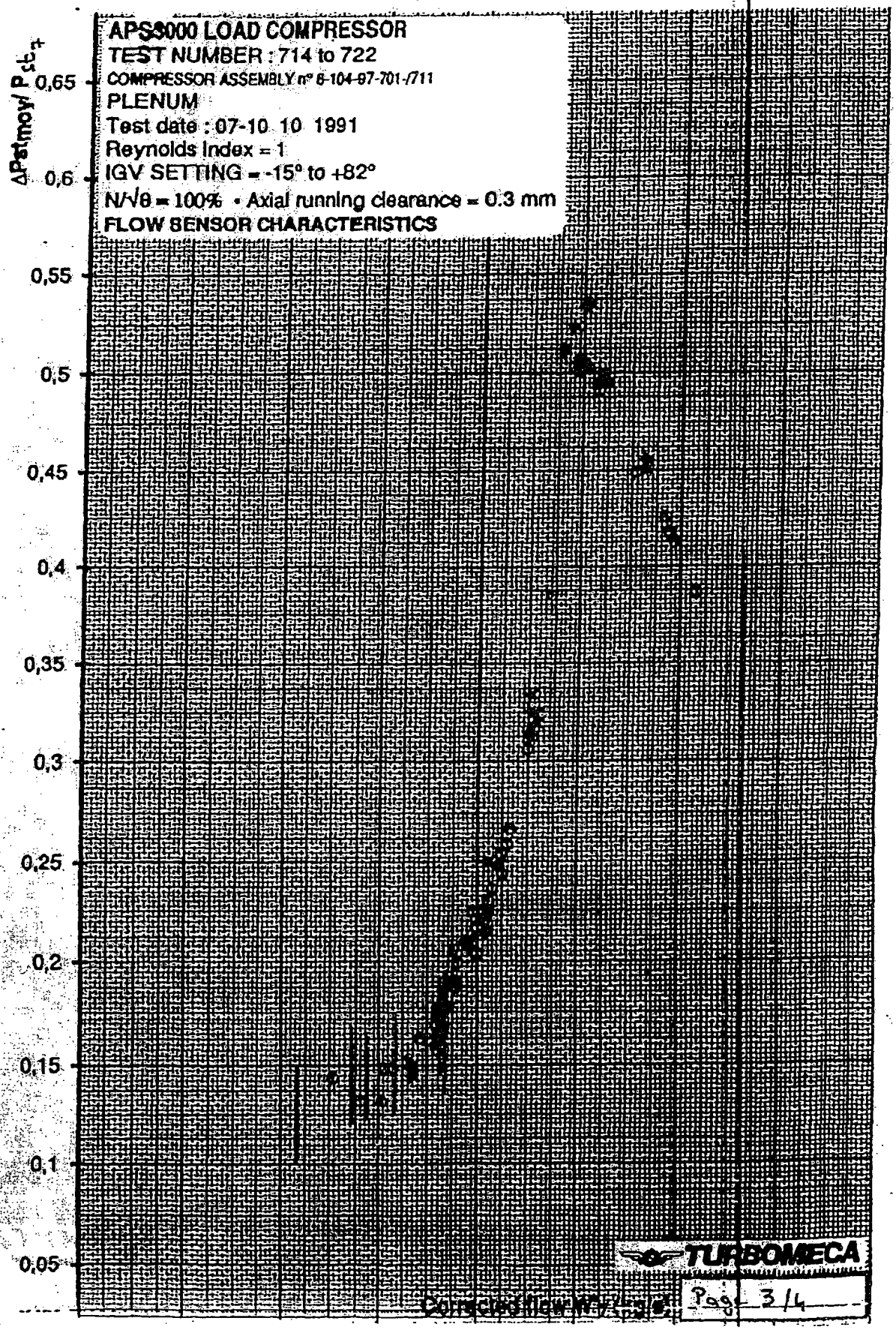
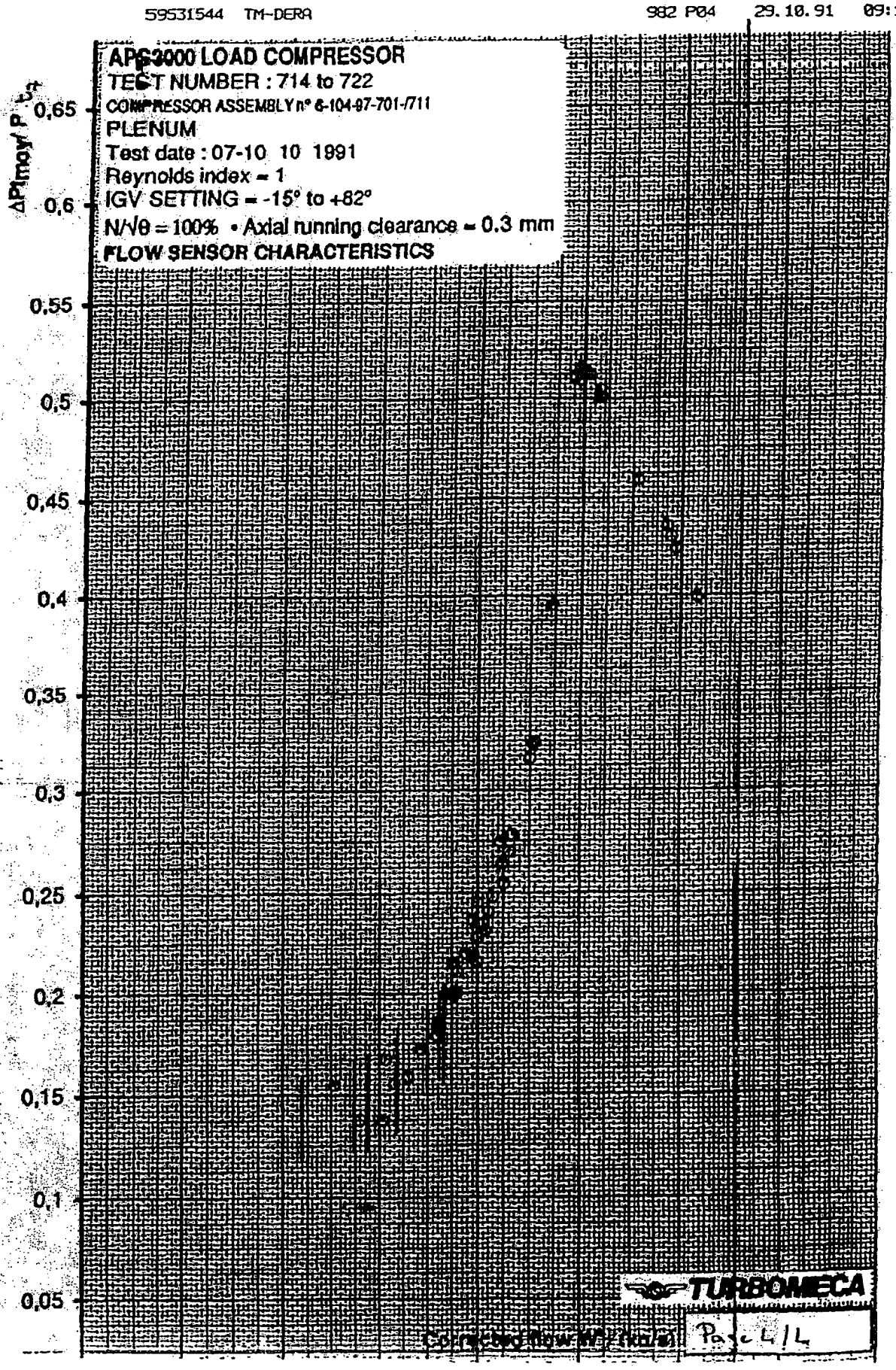
MEMO n° TB 332-0634

If we compare these curves with D1 engine measurements (only 1 pressure tap, with correction due to bigger axial clearance), we can see that points between $\Delta P/P = 0.15$ and 0.4 are inside the scattered rig points, but the slope is a little bit higher.

4. The set point of 0.25 will have to be adjusted (may be lower) when the final scattering will have been assessed (with 19 mps).





Sundstrand Power Systems

Sundstrand Power Systems / TURBOMECA
APS 3000 APU
COORDINATION MEMO

MEMO n° ST 0539
DATE: OCT 1, 1991
REPLY BY: OCT 18, 1991

TO: G HARDY FROM: P.J SUTTE

SUBJECT: LOAD COMPRESSOR FLOW MEASUREMENT

REFERENCE:

The following referenced information is ☒ (or is not ☐) considerd "PROPRIETARY" by the originator

☒ REQUEST
☐ INFORMATION
☐ REPLY TO:

The ECB is required to transmit a calculated value of the load compressor corrected flow, via the ARINC 429, to the A320/A321 onboard computer systems. We planed to accomplish this by using the delta p / p vs. W'7 plot supplied by Turbomeca (TS332-0428). This plot, however, has a double solution for delta p / p values greater than 0.34.,which interferes with our ability to transmit the correct load compressor flow. What is Turbomeca's view of this issue ?

Surge control will not be greatly affected by this double solution phenomenon, assuming that the delta p / p value does not continue decreasing with increasing corrected flow, thereby approaching the set point of 0.25. Does the plot extend further with increasing flow, beyond the minimum value of approximately 0.34 ?

These plots note IGV angles of 0 and 10 degrees. How will different IGV angles (especially 88 deg, closed) affect these plots ?

We currently have load compressor efficiency and flow data for IGV angles up to 60 deg. Please supply efficiency and flow data for the closed IGV position

When this information is received and agreement is reached, I will prepare an ICD on this subject.

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APPROVED BY: [signature] DATE: 1 Oct 91

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PTX 1066

HAMILTON STANDARD
Internal Correspondence CD 268

April 23, 1969

Memorandum to: Mr. R. A. Moser

cc: Messrs. A. L. Bates, R. J. Brown, P. E. Cosman, B. Davison, K. I. Harner, P. E. Holland, F. Kahoun, W. K. Wells

From: Mr. A. F. Rapp

Subject: Dynamic Analysis of the Surge Control for the L-1011 APU
WPI: 651-D31-000A

Introduction

The L-1011 APU has been provided with a modulated flow control valve which has the capability of bypassing the APU load compressor discharge flow to ambient when ECS flow demands are such as to attempt to drive the load compressor into surge. This memorandum summarizes the results of the dynamic analysis performed on this surge control valve. A linearized analysis was performed to define system gains at various operating conditions, and the transient response of the surge control to ramp disturbances in ECS demand flow was determined using a non-linear MIMIC digital computer simulation.

System Description

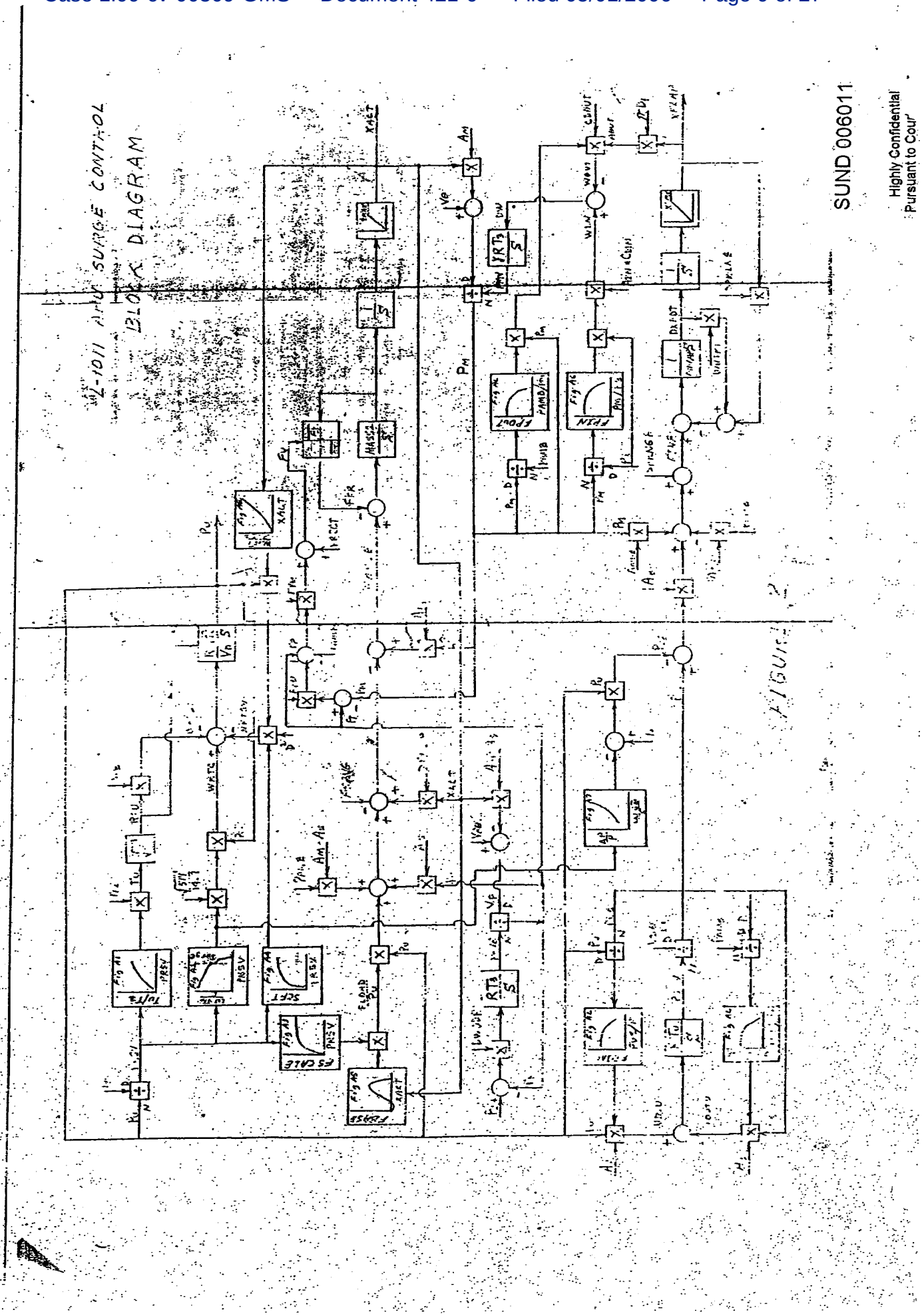
A simplified schematic of the surge control is shown in Figure 1-A. As shown in this figure, a "force-balance" sensor with one flowing chamber is used to indicate the magnitude of the corrected flow passing through the diffuser section of the load compressor. A corrected flow less than a preset minimum will cause the sensor flapper to close, building up modulated pressure to the point where the actuator can drive open the surge control valve. The opening of the valve is opposed by supply pressure, friction and valve aerodynamic loads. A spring load insures that the surge control valve will be in the open position during start-up.

Assumptions and Restrictions

The following assumptions were made in order to carry out the surge control analysis:

1. The static pressure measured at the downstream pressure tap on the load compressor is equal to the load compressor discharge total pressure, PU. For Mach numbers at this station less than 0.2 this assumption is good to within 3%.

2. The duct pressure losses downstream of the surge control valve are negligible and therefore the valve discharges to ambient pressure.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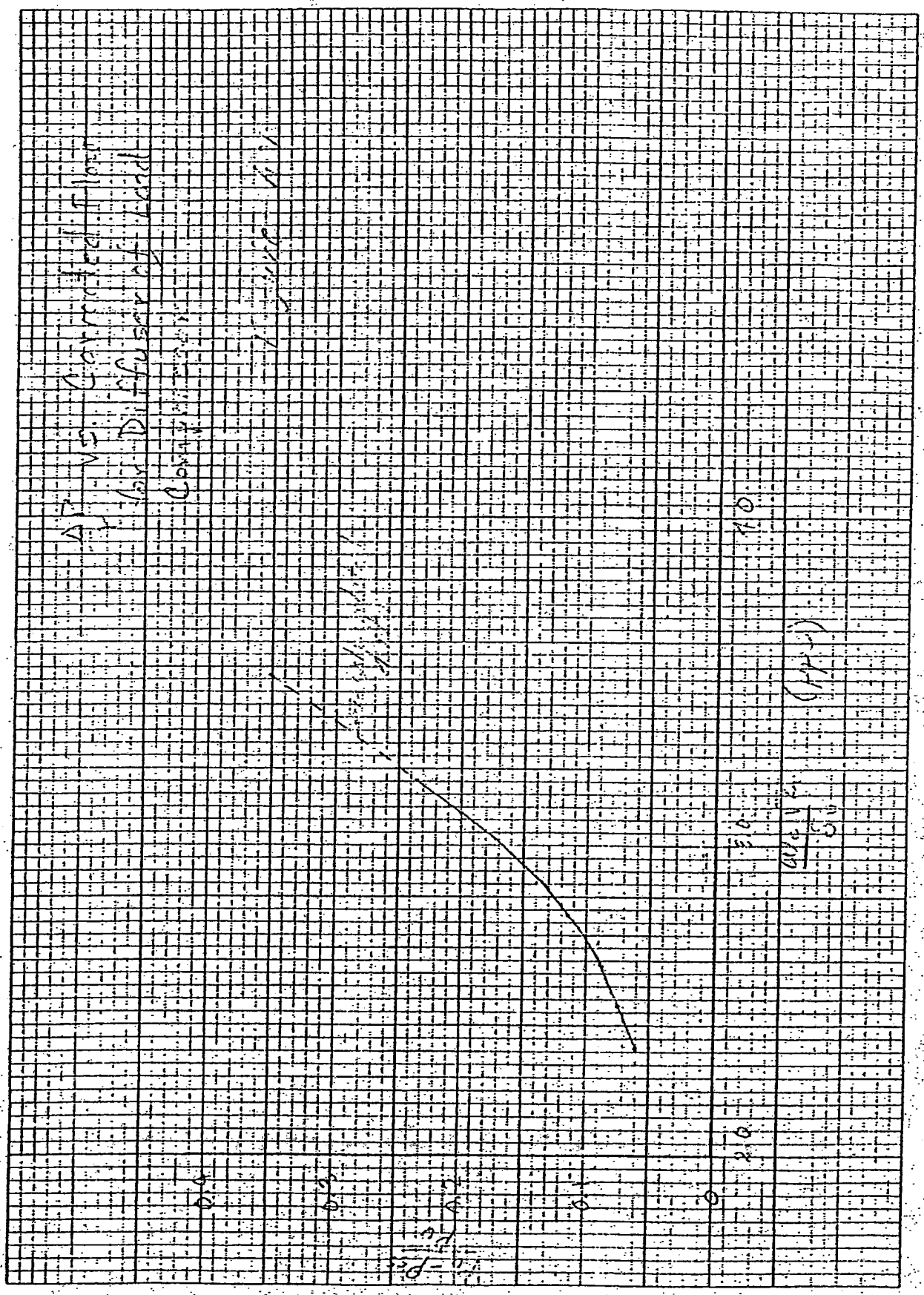

PTX 1104

TURBOMECA

Sundstrand Power Systems / TURBOMECA
APS 3000 APU
COORDINATION MEMO

MEMO n° TS-332-0827
DATE: 23 June, 92
REPLY BY:

TO: P. MARTENS / S. GATES FROM: D. TUQUOI
A. DUCROCQ
SUBJECT: ΔP measurement
REFERENCE:
The following referenced information is ☐ (or is not ☒) considered "PROPRIETARY" by the originator

☐ REQUEST
☒ INFORMATION
☐ REPLY TO: ST-0998

I apologize for the delay in my answer. In fact that parameter was never measured vs. time. So we have conduct a test on a GTCP 331-350 L/c module yesterday (no module where available before).
The traces attached give the value of the static pressure in the diffuser (average value of 19 holes).
As you can see the traces are absolutely flat, no noise is recorded. The signal measured is rough, without any filtering.
We don't see any reason to have a different signal on the qual. APS 3000.

Best regards.

Copy: KOULOSTI
GILGUBEL
LAMPE
M'ARTHUR

PEF 6/23

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APPROVED BY: G. Hardy P.O. DATE: 23 June 92

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Page 1 of 3

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PTX 1104

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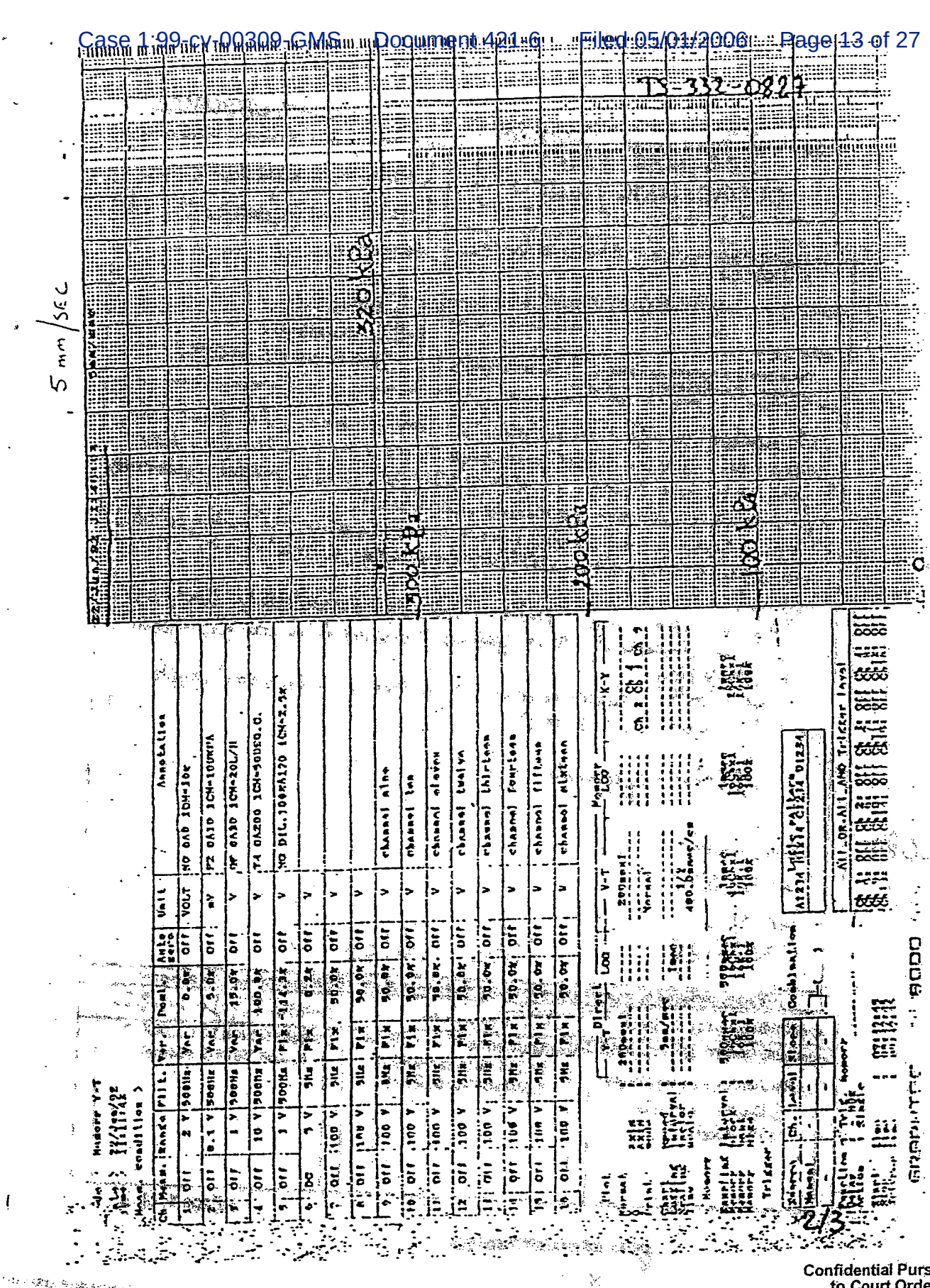

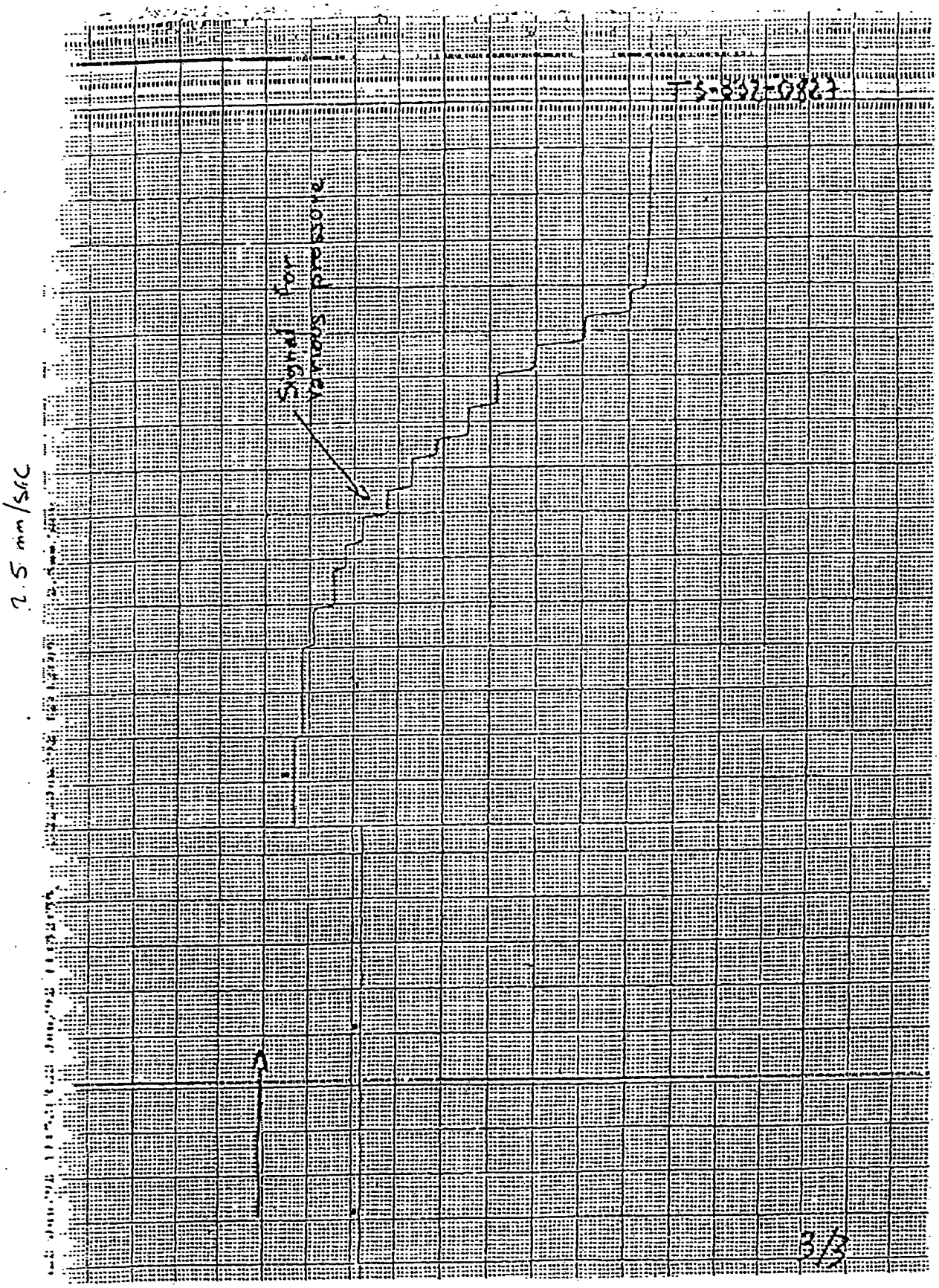

PTX 1114

memo

Power Systems | SUNDSTRAND AEROSPACE

CC: B. Edelman
T. Maedche
M. Juett
S. Lampe

Date: 2-1-93

To: P. Suttie

From: K. Mehr-Ayin

Subject: B factor calculations

The latest test data obtained during 1-30-93 & 1-31-93 testing, which included the raw input values for all analog inputs, were used to calculate the B factor. Attached are the manual calculations for two cases that were captured using the RS-232 command. These calculations consider the software compensations that are used to account for the harness and ECB resistances. In both cases the ECB is correctly interpreting the inputs as being on the left side of the flow curve. However, in case 1 the load compressor is physically operating on the right side of the curve, and since the delta-p/p (0.22) value is less than the setpoint (0.25), the ECB correctly commands the BCV to mid position.
Based on the available data it seems that the ECB is correctly calculating the B factor and the algorithm may have to be re-evaluated.

REMAND
PTX 1114

DEPOSITION EXHIBIT 239

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HSB 260155

3.85 m/c

CASE 1

CNTS

$T_2 = 2632 \rightarrow R = 1115.99 - 19.04 - 1.2 = 1095.75 \rightarrow T_2 = 24.87°C$

$\Delta P = 1023 \rightarrow \Delta P = 6.86$ Psid

$P_2 = 3410 \rightarrow P_2 = 13.72$ psia

$P_S = 1148 \rightarrow P_S = 30.81$ psia

LCCT = 2975 $\rightarrow R = 1839.37 - 68 - 1.2 = 1770.17$ $T_{LCO} = 200°C$

$$B = \frac{P_S - \Delta P}{P_2} \times \frac{T_2}{T_{LCO} - T_{W1}} = \frac{30.81 - 6.86}{13.72} \times \frac{(24.87+273)}{200 - 24.87}$$

$B = 2.9691$

Case 1: IGV POS = 100% $B_C = 2.85$ $B > B_C \rightarrow$ LEFT SIDE

$\Delta P/P$ Setpoint = 0.25 Actual $\Delta P/P = 0.222$

CASE 2

CNTS

$T_2 = 2688 \rightarrow R = 1124.29 - 19.04 - 1.2 = 1104.05 \rightarrow T_2 = 27.03°C$

$\Delta P = 2010 \rightarrow \Delta P = 13.49$ Psid

$P_2 = 3407$ $P_2 = 13.71$ psia

$P_S = 2015$ $P_S = 54.07$ psia

$T_{LCO} = 3007$ $R = 1853.34 - 68 - 1.2 = 1784.14 \rightarrow T_{LCO} = 203.67°C$

Case 2: IGV = 100% $B_C = 2.85$

$$B = \frac{54.07 - 13.49}{13.71} \times \frac{(27.03+273)}{203.67 - 27.03} = 5.02$$

$B > B_C$ LEFT

ON CONTROL $\rightarrow \Delta P/P = 0.249$

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HSB 260156

PTX 1133

Sundstrand Power Systems / TURBOMECA
APS-3200 APU
COORDINATION MEMO

Sundstrand Power Systems

MEMO No. ST- 2325

DATE: 9 Sep 94

REPLY BY:

TO: Tuquoi/Nasarre & Desnoyer FROM: P.J.Suttie

SUBJECT: Load Compressor Surge

REFERENCE:

The following referenced information is ☐ (or is not ☐) considered "PROPRIETARY" by the originator

☒ REQUEST

☒ INFORMATION

☒ REPLY TO: TM Fax 9 Sept. 94

1) Compatibility test data is useful but following flight test, large amounts of installed data is also available.This data is truly representative of the Aircraft Production Configuration including the correct valves and volumes.

SPS has already reviewed this flight test data and found only one case of APU load compressor surge (@20,000 ft). Modification (PCR 1075) has already been incorporated into the ECB software to correct this.
SPS will review this data again in light of recent APU in-services failures.

2) DP/P sensors received from the field have all been bench tested at SPS - all either tested ok or were marginally out of tolerance.

The specific fault message which diagnoses DP/P sensor faults arises when DP is less that 1.75 psi. Turbomeca has suggested (and I agree) that this could occur in the case when MES valve opens and an ECS valve does not close.
The investigation of this is proceeding using the A320/A321 Aircraft Integrated Data System (AIDS). This will occur at AFA and ITF and will provide a history recording of Pneumatic parameters including valve positions and pressures during MES on in-service A/C.

This data may also be useful in determining is surge is occurring in production A/C. However if Turbomeca has some suggestions of when a Load Compressor surge may be occurring, please provide to DA. This will allow a special AIDS Report to be generated.

However, a humidity/temperature test will be performed on a DP/P sensor to ensure that no sensor problems are present.

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APPROVED BY: DATE: 9/9/94

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	L. GINSBURG	

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HSB 040317

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APS-3200 APU
COORDINATION MEMO

Sundstrand Power Systems

MEMO No. ST-2325

3) The BCV opening/closing time is 125 msec full stroke. This is extremely fast for a valve of this size and is limited by the fuel pressure and actuator piston size. It is doubtful, if any improvement could be made in the response of this valve and even if it were, this does not explain the required sustained surge.

APU shutdown logic for surge protection. Please supply details of the surge tests carried out at Turbomeca; specifically, the relationship between DP/P, APU intake temp. sensor P/N 4950036 and APU surge. This will allow SPS to possibly devise an algorithm to "detect" surge and cause an APU shutdown.
SPS will review the NVM data from the ECBs which controlled the APUs which failed (IGV lock-up). If the Turbomeca theory is correct one would expect to see Intake Temperature sensor failure messages when the intake temperature rose above 76 deg C. This assumes that this temperature rise can be detected by the APU sensor which is located on the Power Compressor side of the plenum.

URGENT: The design freeze for Version 3.0 Software is 30 Sept. 1994.

Although SPS has only received verbal information from Turbomeca as yet on the results of the recent surge tests, it seems apparent that surge conditions must last for a significant period to cause the IGV Bushing temperature to rise sufficiently to deform. 1 minute 45 seconds has been quoted.

From the point of view of the control system this is steady state operation.

Load compressor surge can only occur steady state if the DP/P is at the 0.2 setpoint and surge is occurring (ie zero surge margin) or if the 'B' factor is incorrectly stating which side of the DP/P vs. flow curve that the load compressor is operating on.(the ECB calculates a B factor and determines that the flow is high and in fact the flow is low and the compressor is in surge).
BCV mechanical problems could also potentially cause the problem but this would have to be combined with an ECB fault detection problem. The BCVs on the failed APUs worked correctly and the ECB BCV fault logic has not been reported as problematic so this is a less likely possibility.

Turbomeca is requested to review their requirements for:

1) DP/P Setpoint
2) 'B' Factor Operation

As stated in ICD 02/08/001.

SPS realizes the serious nature of this problem and will commit the necessary resources to assist Turbomeca in accomplishing a rapid solution.

Best Regards

PTX 1134

Sundstrand Power Systems

Sundstrand Power Systems / TURBOMECA
APS-3200 APU
COORDINATION MEMO

MEMO No. ST-2336

DATE: 26 Sep 94

REPLY BY:

TO: D. Tuquoi FROM: Jayne Lanham

SUBJECT: APS 3200 'Surge' Program Plan

REFERENCE:

The following referenced information is ☐ (or is not ☐) considered "PROPRIETARY" by the originator

☐ REQUEST

☒ INFORMATION

☐ REPLY TO:

The following is SPS's input for the 'Surge' Program Plan.

Sundstrand is currently working in three key areas of investigation. It is our plan to have these efforts completed in the next two weeks.

1. Per Ed Edelman's discussion with TM, Sundstrand has undertaken evaluation of the contribution which a)Sensor Variation, b)Dynamic Undershoot, c) Control Response (including signal filtering) to variation in system surge margin.

Included in this effort is completion of the Delta P/P Sensor humidity test (which has been delayed to facility problem which is currently being worked). Also included in this effort would be evaluation of sensor performance from engines identified to have operated in surge.

It is anticipated that Turbomeca will be pursuing the evalution of Engine-to-Engine variation and engine deterioration.

2. Sundstrand will work with the airlines and APIC customer support to acquire operational data which could help identify under what conditions surge is occuring. This will be a joint effort with Turbomeca. SPS will take the lead in such discussions with UAL in this issue. It is understood that their DMU will likely not be operational until the end of the year, but we will be discussing with them other options (such as pilot queries, etc.)

3. Sundstrand will evaluate methods of 'sensing' surge and evaluate these options for inclusion in Version 3.0 software. Some ideas currently under consideration are:
   a) Delta Temperature across Load Compressor
   b) Moving the inlet temperature sensor
   c) Gaging with Delta P/P Level and Rate of Change

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APPROVED BY: JLanham DATE: 9/26/94

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Sundstrand Power Systems
MEMO No. ST-2336

During our discussions regarding this issue, some other areas for evaluation, which fall in more in Turbomeca's area of responsibility, were raised. Turbomeca may wish to consider the following:

1. Evaluate increasing the Delta P/P Setpoint

2. Possiblity of eliminating T7 from the B-Factor Calculation in order to provide a more reliable b-factor.

3. Eliminate the dual solution of B-Factor by moving the diffuser holes.

We hope that this input will aide in the preparation the the Program Plan addressing this issue. If there are other actions which you feel SPS should be taking, we can discuss them in the videocon tomorrow.

'See' you tomorrow! Best Regards --

PTX 1140

Sundstrand Power Systems

Sundstrand Power Systems / TURBOMECA
APS-3200 APU
COORDINATION MEMO

MEMO No. ST-1190
DATE: 9/16/92
REPLY BY: 9/18/92

TO: G. Hardy FROM: P.J.SUTTIE

SUBJECT: LOAD COMPRESSOR AIRFLOW MEASUREMENT

REFERENCE:

The following referenced information is ☐ (or is not ☐) considered "PROPRIETARY" by the originator

☒ REQUEST
☒ INFORMATION
☐ REPLY TO:

SPS HAS RECENTLY TESTED Q22 IN THE DA TAILCONE. ATTACHED PLEASE FIND A COMPARISON PLOT SHOWING THE DIFFERENCES BETWEEN D2 (1 HOLE DIFFUSER) AND Q22 (19 HOLE DIFFUSER) BOTH IN THE TAILCONE. THIS REPRESENTS A DIRECT "BACK TO BACK" COMPARISON. AS YOU CAN SEE THERE IS A REDUCTION IN THE SIGNAL TO NOISE RATIO HOWEVER THE LEVELS OF NOISE ON THE DELTA PRESSURE SIGNAL WILL STILL PREVENT ACCEPTABLE CLOSED LOOP CONTROL OF THE LOAD COMPRESSOR.

SPS HAS PERFORMED A SERIES OF DEVELOPMENTAL TESTS ON THE AIRFLOW SENSING/ LOAD COMPRESSOR SYSTEM WHICH HAVE BEEN DOCUMENTED IN COORDINATION MEMOS OVER THE LAST 4 MONTHS.
TO DATE THESE TESTS HAVE BEEN UNSUCCESSFUL IN ELIMINATING THE SIGNAL NOISE OR IN IDENTIFYING ITS SOURCE.

TESTING PERFORMED BY TURBOMECA ON THE 1 HOLE DIFFUSER HAS SHOWN INDICATIONS OF A SIMILAR NOISE (RBF 0674) HOWEVER PREVIOUS DATA HAD SHOWN LIMITED NOISE (TS-332-0862 & TS-332-0897) AND THE 19 HOLE DIFFUSER CONFIGURATION SHOWS LOW NOISE.
NO CORRELATION HAS BEEN MADE BETWEEN THE TURBOMECA AND SPS RESULTS.

THE PRESSURE SIGNAL FROM THE LOAD COMPRESSOR DIFFUSER IS NOT SUITABLE FOR THE HIGH GAIN FAST RESPONSE CONTROL LOOP NECESSARY FOR SURGE PROTECTION. AS THIS IS PART OF THE INTERFACE BETWEEN TURBOMECA AND SPS , SPS REQUESTS THAT TURBOMECA REVIEW THE DESIGN OF THE DIFFUSER PRESSURE SOURCE WITH A VIEW TO REDUCING THE LEVEL OF NOISE. AS THIS PHENOMENA CANNOT BE REPRODUCED BY TURBOMECA I SUGGEST THAT A REPRESENTATIVE OF TM COME TO SPS TO REVIEW THE TEST SET UP AND DISCUSS A PLAN THAT THE JOINT VENTURE CAN PROCEED WITH.
AT THIS TIME WE DO NOT HAVE AN ACCEPTABLE SYSTEM TO QUALIFY OR

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APPROVED BY: DATE: 9/16/92

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Sundstrand Power Systems / TURBOMECA

APS-3200 APU

COORDINATION MEMO

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